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A CASE STUDY:
INTRODUCTORY CHEMISTRY AT UW-MADISON

What follows is a case study that illustrates use of the planning methodology.

<u>Background</u>

Introductory Chemistry at UW-Madison currently enrolls over 5,000 students per year. A major problem in introductory chemistry is that students come to UW-Madison (and to most other colleges and universities) from a wide variety of educational backgrounds. Some have a strong pre-college experience from an excellent high school; others have an inadequate chemistry background; still others have had no high school chemistry. Many have deficiencies in specific aspects of chemistry. Thus their knowledge and skill levels vary widely. Such a range of preparation means that some need to learn more quickly, while others have a stronger base upon which to build. At present it is difficult to deal with this broad range of student preparation because little individualization of instruction is possible. Except for placing students into different courses on the basis of mathematics test scores, little is done to adapt the University's offerings to students' backgrounds and abilities.

Approximately half of the freshmen at UW-Madison enroll in Chemistry 103, the first of the two-semester sequence to be affected by this project. After taking the introductory course, students flow into a variety of programs in which chemistry serves as a foundation study such as nursing, biology, engineering, etc. Thus, any improvements in the introductory course will have a significant impact on a broad range of departments throughout the sciences and engineering. The chemistry department has on several occasions surveyed faculty in these client disciplines to get their opinions about what is appropriate content for introductory chemistry and to ascertain how well what students learn in these courses is being carried over into courses in other disciplines. The results show that the course content is appropriate, but students' retention of what they have learned is not. In addition, their ability to apply concepts learned in earlier chemistry courses is not rated highly by those teaching subsequent courses in chemistry or in client disciplines.

Led by Professor X, a team composed of faculty, IT professionals, and graduate and undergraduate students has made significant strides in the development of interactive Web-based pre-laboratory exercises and other individualized technology-mediated activities. This has been accomplished through a grant to UW-Madison from the National Science Foundation that involves a coalition of colleges, universities, and two-year colleges working to develop and evaluate new ways to teach undergraduate chemistry. However, the Web-based materials developed to date are only a part of what is needed for a comprehensive approach to reforming the introductory chemistry course.

The intended redesigned course has the potential to individualize instruction and thereby address the problem of varying student backgrounds. It can assess students' knowledge in much smaller subject-matter chunks and provide them feedback and direction that will allow them to make up for specific deficiencies by means of extra work and effort. It also has the potential to help students learn to identify their own deficiencies and do their own remediation, a good habit for lifelong learners to develop early. Another important aspect of the technology-based materials is to provide a means by which chemistry can be reviewed by students in subsequent courses, and to bring into those materials examples and information from other disciplines that will help students to see the applications of the chemistry they are learning.

The academic problems to be addressed can be summarized as follows:

- inconsistency of student academic foundation in chemistry, which causes many students to have problems in general chemistry;
- inadequate student interaction with learning materials;
- difficulty in tracking multiple student experiences in large classes;
- inability to accommodate different student learning styles;
- insufficient (or nonexistent) connections in students' minds between chemistry and the many other disciplines that require chemistry courses.

In summary, the way that chemistry is learned at the University of Wisconsin-Madison will be redesigned with the following objectives: to improve productivity, student learning, and long-term retention of what students have learned through the incorporation of Web-based interactive learning materials. The supporting materials will consist of compelling on-line, interactive modular content with tutorial and assessment functionality. The system will be flexible, easy-to-use, and designed to work well on today's established technological infrastructure. It will also be designed to be easily upgraded as technology improves. Once validated, the redesigned course will provide a model of excellence for many others to follow. Because it will be delivered via the Web, it can be adopted easily by other UW campuses and other universities throughout the country.

Traditional Course Structure

The current chemistry course is organized as follows:

The course meets for 15 weeks. There are eight sections of the course.

Each section enrolls 350 students:
- 350 students in a lecture
- 22 students in each discussion section and lab (22*16 = 352)

6 contact hours per week + 1 exam/quiz period
- 2 one-hour lectures per week
- 2 one-hour discussions session per week
- 1 two-hour lab per week
- 1 one-hour quiz/exam hour per week (11 quizzes, 3 exams, 1 final)

A professor teaches one section of the course with the following responsibilities:
- 2 lectures per week
- 11 quizzes, 4 exams
- 1 office hour per week
- Supervise 8 TAs

8 TAs assist in teaching each course section with the following responsibilities:
- Attend lectures
- Proctor and grade exams
- Prepare and grade quizzes
- Lead 2 discussion hours per week
- Lead 2 lab hours per week
- Attend orientation and staff meetings

Instructional Costs per Hour

UW calculated the hourly costs of one professor, 8 TAs and 4 support positions for the current course. (Note: The salary figure used in the example represents the average salary of the eight professors who teach Chemistry 103.)

In this example, only salary is included; benefits are not included.

Faculty

Salary	$89,538

% devoted to instruction	50%
% devoted to this course	50%
$ devoted to this course	$22,385

Contact hours for course	30
Out of class hours	140
Total hours	170
Cost per hour	$132

TAs/GAs

Salary for 1 TA	$32,618
% devoted to instruction	50%
% devoted to this course	50%
$ devoted to this course	$8,155

Contact hours for course	116
Out of class hours	244
Total hours	360
Cost per hour	$23

Support Staff	1	2	3	4
Position:	Lab Manager	Tech Support	Stock-room	Computer room
$ per hour	$19	$29	$12	$7
Total hours	89	67	67	16
Total	$1,656	$1,959	$784	$112

Worksheet: Instructional Costs of Traditional Course

Here is a worksheet that the UW professor used to determine current course costs. It presents instructional tasks as we usually think of them.

- Number of hours = weeks per term * sessions per week * session length expressed as an hour or percentage of an hour
- Total cost = # of hours * personnel cost per hour

	Weeks per term	Sessions per week	Session length/hr	No of sections	Hours for 1 TA	Contact hours	Cost/ hour	Total Cost
Faculty								
Lecture	15	2	1	1		30	$132	$3,950
Lecture prep	15	2	2	1		60	$132	$7,900
Staff meeting	15	1	1	1		15	$132	$1,975
Quiz proctor	11	1	1	1		11	$132	$1,448
Exam prep	4	1	3	1		12	$132	$1,580
Exam grading	4	1	3	1		12	$132	$1,580
Office hours	15	1	2	1		30	$132	$3,950
Faculty Sub-total						170		$22,384
TAs								
In-Class								
Lect attend	15	2	1	8	30	240	$23	$5,436
Discussion	15	2	1	16	60	480	$23	$10,872

Labs	14	1	2	16	56	448	$23	$10,147
Exam attend	4	1	1	8	4	32	$23	$725
In-Class Sub-total					150	1200	$23	$27,180
Out-of-Class								
Disc prep	15	1	2	8	30	240	$23	$5,436
Lab prep	14	1	2	8	28	224	$23	$5,074
Disc grading	15	1	2	8	30	240	$23	$5,436
Lab grading	14	1	2	8	28	224	$23	$5,074
Quiz prep	11	1	1	8	11	88	$23	$1,993
Quiz grading	11	1	1	8	11	88	$23	$1,993
Exam grading	4	1	3	8	12	96	$23	$2,174
Staff meeting	15	1	1	8	15	120	$23	$2,718
Office hours	15	1	1	8	15	120	$23	$2,718
Orientation	1	5	6	8	30	240	$23	$5,436
Out-of-Class Sub-total					210	1680		$38,052
Sub-total TA					360	2880		$65,232
GRAND TOTAL						3050		$87,616

Instructional Costs of Traditional Course

Here is a translation of the professor's worksheet to the course planning tool:

	FACULTY (Hrly rate=$132)		**TAs/GAs** (Hrly rate=$23)	
	# of Hours	Total Cost	# of Hours	Total Cost
I. Course Development				
A. Curriculum Development				
1. Learning objectives				
2. Course design/sequencing				
3. Evaluation criteria				
Sub-Total				
B. Materials Acquistion				
1. Learning materials/software				
2. Diagnostic assessments				
3. Tests/evaluations				
Sub-Total				
C. Materials Development				
1. Lectures/presentations	60	$7,900	464	$10,510
2. Learning materials/software				
3. Diagnostic assessments				
4. Assignments				
5. Tests/evaluations	12	$1,580	88	$1,993
Sub-Total	**72**	**$9,480**	**552**	**$12,503**
D. Faculty/TA Devmt/Training				
1. Orientation			240	$5,436
2. Staff meetings	15	$1,975	120	$2,718
3. Attend lectures			240	$5,436

Sub-Total	**15**	**$1,975**	**600**	**$13,590**
Total Development	**87**	**$11,455**	**1152**	**$26,093**
II. Course Delivery				
A. Instruction				
1. Diagnose skill/knowledge level				
2. Presentation	30	$3,950		
3. Interaction	30	$3,950	1048	$23,737
4. Progress monitoring				
5. Test proctoring	11		32	$725
6. Tests/evaluation	12		648	$14,677
Total Delivery	**83**	**$10,929**	**1728**	**$39,139**
GRAND TOTAL = $87,616	**170**	**$22,384**	**2880**	**$65,232**

Materials Development--Lectures/presentations includes lab and discussion prep.
Course Delivery—Interaction includes discussion session, labs and office hours.
Course Delivery—Tests/evaluation includes evaluating discussion sessions, labs, quizzes and exams.

Plans for Course Redesign

The UW project plans to develop a modularized, interactive learning environment for introductory chemistry that will allow students to determine what they do not know and then study intensively those areas where they are weak. In addition, the plan includes a core of activities that are self-paced to permit students to focus on group projects and problem solving, either synchronously or asynchronously. This redesign of introductory chemistry will also incorporate the on-line lab modules that are already nearly complete. Because chemistry is a foundation for studies in other fields, each module will incorporate application of chemistry in various fields. Students will be able to access applications of chemistry by alternative pathways so that instruction can be individualized for those students whose academic and career plans will take them in different directions.

The modules created by this project will be digital, interactive, and IMS-compatible. They will be designed to link together in various ways, depending on the learning objectives identified by the faculty and on the specific learning needs of each individual student. Supporting features will include the ability to track students' progress and intervene when they are having difficulty, assess learning as it occurs, and identify a variety of learning resources to assist students.

A typical module will include roughly the same quantity of material as a typical chapter in a general chemistry textbook. However, for many students, not all of the module's content will be needed. Like a book chapter, each module will be divided into sections. Each section will begin with a diagnostic quiz, so that each student can discover immediately those aspects of the section's content that have not been mastered. If the student's quiz shows that all of the content has been mastered, then that student will be allowed to go on to the next section. Potentially a student could test out of every section in a module. For those students who need more study, the diagnostic test will indicate which parts of the section the student needs to study. It will also indicate which parts of the textbook the student should study more intensively. This design is ideal for remedial material, because it immediately points the student in the right direction and allows the student to skip those parts of the material that have already been mastered.

The proposed materials will be designed to provide an evolutionary pathway leading from the current synchronous-attendance model of instruction to an asynchronous, distributed model. In the latter model each student's background, current pedagogical needs, and future aspirations regarding course of study and vocation will be used to create a unique progression through the material. That progression will be mediated by technology that will examine and evaluate each student's progress and design future activities that will be most effective in extending it. The biggest advantage of the new modules is that each student's study time will be structured most effectively and used most efficiently to deal with the areas in which that student is weakest.

Although the materials to be produced could replace most existing course components outright, the plan is initially to use technology to supplement and extend traditional course activities, reducing the time students devote to them. This will provide a pathway toward change that will not inhibit faculty or students who might fear revolutionary change. Some traditional components will be retained for some time and others will be replaced immediately. For example, the diagnostic quizzes in the modules are intended to be formative assessments of the students and will replace traditional quizzes, homework, and recitation sections. However, because of the difficulty of preventing cheating, summative assessments will need to be done outside of the module system, presumably by much the same techniques that are used currently. Existing laboratory modules can carry out pre-laboratory preparation and instruction about laboratory techniques and instruments, but chemistry also requires hands-on manipulations in the laboratory that cannot be done solely by computer simulation. The initial set of modules is expected to replace mainly lecture, discussion, and pre-laboratory aspects of the course.

In summary, the redesigned course will implement the following changes:

- Eliminate 1 lecture per week; replace with interactive software modules.
- Eliminate 1 discussion per week; replace with interactive software modules.
- Students can access modules 24 hours a day, 7 days a week.

- Assume TAs will do no preparation or grading for discussion sections because the software will handle it all.
- Lab sessions are unchanged.
- Add 1 help lab with lab monitor per week.

<u>Cost Savings</u>

By off-loading instructional tasks performed by faculty and teaching assistants in the traditional model to interactive, computer-based learning modules, the projected redesign will result in savings of $172,7300 in personnel costs per semester for the introductory chemistry course.

- Savings for one 350-student section = $21,591 ($87,616 - $66,025)
- Savings per semester (8 sections) = $172,730 ($21,591 * 8)

Faculty Savings : Instructor time goes down by 45 hours; lectures go down from 30 to 15 hours and prep time goes down from 60 hours to 30 hours. While this 45 hours may be only a fraction of the time required to teach the course (170 hours without technology and 125 with technology), one must remember that there are 8 sections of the introductory chemistry course. 8 * 45 = 360 means that 6 professors rather than 8 are required to teach the course.

TA Savings: The total TA time goes from 2880 to 2040 . Since the TA expectation is about 360 hours for a course, UW estimates that it will save 2 TAs for the course—i.e., it will require 6 TAs to do the job of 8.

Worksheet: Instructional Costs of Redesigned Course

Here is a worksheet that the UW professor used to determine the redesigned course tasks and costs.

	Weeks per term	Sessions per week	Session length/hr	No. of sections	Hours 1 TA	Effort hours	Cost/hr	Total Cost
Faculty								
Lecture	15	1	1	1		15	$132	$1,975
Lecture prep	15	1	2	1		30	$132	$3,950
Quiz proctor	11	1	1	1		11	$132	$1,448
Staff meeting	15	1	1	1		15	$132	$1,975
Exam prep	4	1	3	1		12	$132	$1,580
Exam grade	4	1	3	1		12	$132	$1,580
Office hours	15	1	2	1		30	$132	$3,950
Sub-total						125		$16,459
TAs								
In-Class								
Lect attend	15	1	1	8	15	120	$23	$2,718
Discussion	15	1	1	16	30	240	$23	$5,436
Labs	14	1	2	16	56	448	$23	$10,147
Exam attend	4	1	1	8	4	32	$23	$725
					105	840	$23	$19,026
Out-of-Class								
Disc prep	15	1	0	8	0	0	$23	$0
Lab prep	14	1	2	8	28	224	$23	$5,074
Disc grading	15	1	0	8	0	0	$23	$0
Lab grading	14	1	2	8	28	224	$23	$5,074
Quiz prep	11	1	1	8	11	88	$23	$1,993
Quiz grading	11	1	1	8	11	88	$23	$1,993
Exam grading	4	1	3	8	12	96	$23	$2,174
Staff meeting	15	1	1	8	15	120	$23	$2,718
Office hours	15	1	1	8	15	120	$23	$2,718
Orientation	1	5	6	8	30	240	$23	$5,436
					150	1200		$27,180
Sub-total TA					255	2040		$46,206.00
Computer rm support	15	2	1	16		480	$7	$3,360
(All other support staff costs remain the same.)								
GRAND TOTAL								**$66,025**

By off-loading instructional tasks performed by faculty and teaching assistants in the traditional model to interactive, computer-based learning modules, the projected redesign will result in savings of $172,7300 in personnel costs per semester for the introductory chemistry course.

- Savings for one 350-student section = $21,591 ($87,616 - $66,025)
- Savings per semester (8 sections) = $172,730 ($21,591 * 8)

Instructional Costs of Redesigned Course

Here is a translation of the worksheet to the course planning tool format using the UW example.

FUNCTIONS	FACULTY		TAs/GAs	
	# of Hours	Total Cost	# of Hours	Total Cost
I. Course Development				
A. Curriculum Development				
1. Learning objectives				
2. Course design/sequencing				
3. Evaluation criteria				
Sub-Total				
B. Materials Acquistion				
1. Learning materials/software				
2. Diagnostic assessments				
3. Tests/evaluations				
Sub-Total				
C. Materials Development				
1. Lectures/presentations	15	$1,975	224	$5,074
2. Learning materials/software				
3. Diagnostic assessments				
4. Assignments				
5. Tests/evaluations	12	$1,580	88	$1,993
Sub-Total	**27**	**$3,555**	**312**	**$7,067**
D. Faculty/TA Devmt/Training				
1. Orientation			240	$5,436
2. Staff meetings	15	$1,975	120	$2,718
3. Attend lectures			120	$2,718
Sub-Total	**15**	**$1,975**	**480**	**$10,872**

Total Development	**42**	**$5,530**	**792**	**$17,939**
II. Course Delivery				
A. Instruction				
1. Diagnose skill/knowledge level				
2. Presentation	30	$3,950		
3. Interaction 4. Progress monitoring	30	$3,950	808	$18,301
5. Test proctoring	11		32	$725
6. Tests/evaluation	12		408	$9,241
Total Delivery	**83**	**$10,929**	**1248**	**$28,267**
GRAND TOTAL = $62,665	**125**	**$16,459**	**2040**	**$46,206**

Computer room support = 480 hours @ $7 = $3,360
(All other support staff costs remain the same.)

$3,360 + $62,665 = $66,025